HERSCHEL-PLANCK

MISSION IMPLEMENTATION REQUIREMENTS DOCUMENT

(H/P MIRD)

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Reference	SCI-PT-8818
Issue	1
Revision	4
date of issue	1 July 2004

Distribution	**ESTEC**: T. Passvogel, P. Estaria, A. Elfving **ESOC**: Dept. Heads, Div. Heads, Ground Segment Team

CHANGE LOG

reason for change	Issue	revision	date
Formal Issue 1	1	0	15th Dec. 2001
Updates following Project review	1	1	25 Mar. 02
Update following CRR, signature version	1	2	10 April 2002
Update following MIP Issue 1	1	3	05 May 2003
Update prior to GSDR	1	4	1 July 2004

CHANGE RECORD

details of change	page(s)	Section/paragraph(s)
Issue 1	All	All
Issue 1.1		
Fig. 1.1 removed		1.1
AD-11 to AD-16: Instrument Description corrected		1.3
Separation clarified		1.6.2 para 1
"baseline" added		1.6.3
Clarifications		1.6.5
Clarification		2.4
MASS-005, MASS-010,MASS-015, MASS-030, MASS-040,MASS-050, MASS-060, MASS-062, MASS-075, MASS112, MASS-150, MASS-170, MASS-175, MASS-195.		
MFUN-020, MFUN-030, MFUN-170,MFUN-180, MFUN-185, MFUN-200, MFUN-215, MFUN-245, MFUN-260, MFUN 320, MFUN-350, MFUN-390,MFUM-470, MFUN-505, MFUN-630		
MPER-0101, MPER-040, MPER-130, MPER-135, MPER-160, MPER-185, MPER-205, MPER-270		
MPA-075		
New acronyms	40	Acronym list
Issue 1.2		
PDR date	13	1.8.1
MASS-080,		
MFUN 555, MFUN 605,		
MPER 025, MPER-040, MPER-045, MPER-065,		
MOPS-010, MOPS-020, MOPS-170,		
MMAN-095		
Issue 1.3		
MASS-110 details of VCs removed	18	3.6
MASS-140 medium data rate corrected to 150Kbps	19	3.7
MFUN-225 more precise definition of modelling required	23	4.4
MFUN-235 – remove "maintenance of link budgets"	23	4.4
MFUN-620 – ESOC will develop the payload simulators	28	4.11
MFUN-625 – PL simulators will be functional simulators	28	4.11
MOPS-165 – Replace "occurrence" with "detection"	34	6.3

details of change	page(s)	Section/paragraph(s)
MMAN-095 – Manpower reporting requirement modified	40	8.3
Issue 1.4		
Replace TOS Directorate titles with OPS or Operations	Various	Various
Launcher change to ECA and launch date less specific	6	1.1 para. 2
Applicable Documents added	7	1.3
Reference Documents added	8	1.4
Spin axis direction for Planck added	9	1.6.2
Added reference to RD-16, deleted "baseline"	10	1.6.3
Clarification only Herschel has VMC.	10	1.6.4
TBC deleted	11	1.6.5
Spacecraft Milestones updated	12	1.8.1
Operations Ground Segment Milestones updated	13	1.8.2
SVT dates modified according to new spacecraft milestones.	14	2.4
MASS-005 – Launcher changed to E/CA	16	3.1
MASS-015 – Orbit dimensions shown approximate, TBC removed	16	3.3
MASS-080 – TBC removed	18	3.5.4
MFUN-135 – Planck no longer require the planning skeleton	22	4.3
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MFUN-155 – PSO will provide a planned pointing list. No software to be produced by MOC	23	4.3
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MFUN-316 – Deleted, PGSSE meeting #9	24	4.5
MFUN-360 – STR/FSS calibration and note deleted	25	4.6
MFUN-380 – TBC deleted	25	4.7
MFUN-475 – TBC deleted	26	4.9
MFUN-485 – TBC deleted	26	4.9
MFUN-505 – Deleted: the transfer mechanism of RMC and VC data from the ground station to the MOC does not need to be specified in the MIRD	27	4.9
MFUN-550 – TBC removed.	27	4.9
MFUN-600 – VMC and RMC data shall be processed and displayed in the MOC	28	4.11
MFUN-620 – Modified to show ESOC also responsible for payload and instrument simulators	28	4.11
MFUN-635 – MOC to provide Orbit data to JPL	28	4.11
MFUN-640 – New: Updated to show SSO data coming from JPL.	28	4.11
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MPER-130 – Deleted in favour of MPER-140 and MPER-145	30	5.5
MPER-135 – TBD replaced by 0.25arcsec. Relative velocity requirement deleted as covered by velocity error in the SSO ephemerides and the orbit prediction/determination MPER-140,145	30	5.5
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1 INTRODUCTION

This document –the Herschel/Planck Mission Implementation Requirements Document (H/P MIRD)- establishes the baseline for the technical and management requirements applicable to the tasks to be carried out by ESOC in order to implement the Herschel / Planck programme. It establishes, with its counterpart, The Mission Implementation Plan -MIP- produced by ESOC, the customer (Herschel/Planck Project) – supplier (ESOC) relationship as defined in RD-1. It is compliant with ISO 9001. The document generally follows the layout prescribed by RD-2. This layout is applicable to the MIRD's generated within ESOC. The Herschel/Planck Project is defined as an ESOC "Internal Customer".

The Herschel / Planck programme consists of two missions, the Herschel mission and the Planck mission. The Herschel satellite and the Planck satellite will be launched together (dual launch configuration) by an A5 ECA in 2007. This MIRD covers **both** missions. Many requirements in the MIRD are common to both missions. They are labelled H/P. Requirements specific to Herschel are labelled H, requirements specific to Planck are labelled P.

The MIRD is a top-level requirements document with a corresponding level of detail. Responsibility for its generation and maintenance throughout the lifetime of the H/P project lies with the H/P Project Team.

1.1 Scope of Document

The Mission Implementation Requirements Document defines the products and services to be provided by ESOC. It defines the objectives, responsibilities and assumptions and technical/management requirements applicable to ESOC.

Changes to this document could result in changes to cost, schedule or performance of the ground system or services. As the MIRD establishes an agreement between ESOC and the H/P Project, any modification to the MIRD requires formal approval of the Project Manager.

1.2 Abbreviations

The list of acronyms can be found in Appendix 1.

1.3 Applicable Documents

The following documents of the latest issue form part of this specification.

In the event of a conflict between this document and other applicable documents, the conflict shall be brought to the attention of the H/P Project Manager.

In the case of a conflict between this document and reference documents, this document shall have precedence.

AD-1 Herschel/Planck System Requirements Specification, Document no. SCI-PT-RS-05991

AD-2 Herschel/Planck Space to Ground Interface Control Document (RF link) –SG-ICD, Document SCI-PT-ICD-07418

AD-3 Herschel/Planck Operations Interface Requirements Document, Document no. SCI-PT-RS-07360

AD-4 Herschel/Planck Packet Structure Interface Control Document – PS-ICD, Document no. SCI-PT-ICD-07527

AD-5 Herschel/Planck Consolidated Report on Mission analysis –FP-CReMA, Document no. FP-MA-RP-0010-OPS/GMA

AD-6 Telemetry Channel Coding Standard, ESA PSS-04-103, Issue 1, Sept 1989

AD-7 Ranging Standard, ESA PSS-04-104 Issue 2, March 1991

AD-8 Radio Frequency and Modulation Standard, ESA-PSS-04-105 Issue 2.4, Nov 1996

AD-9 Packet Telemetry Standard, ESA-PSS-04-106, Issue 1, Jan 1988

AD-10 Packet Telecommand Standard, ESA-PSS-04-107, Issue 2, Apr 1992

AD-11 Instrument Interface Document, Part B (IID-B): Herschel Heterodyne Instrument, Document no. SCI-PT-IIDB/HIFI-02125

AD-12 Instrument Interface Document, Part B (IID-B): Herschel Photodetector, Array Camera and Spectrometer Instrument, Document no. SCI-PT-IIDB/PACS-02126

AD-13 Instrument Interface Document, Part B (IID-B): Herschel Spectral and Photometric Imaging Receiver Instrument, Document no. SCI-PT-IIDB/SPIRE-02124

AD-14 Instrument Interface Document, Part B (IID-B): Planck High Frequency Instrument, Document no. SCI-PT-IIDB/HFI-04141

AD-15 Instrument Interface Document, Part B (IID-B): Planck Low Frequency Instrument, Document no. SCI-PT-IIDB/LFI-04142

AD-16 Herschel Ground Segment Interface Requirements Document, Document no. FIRST/HSC/DOC/0117

AD-17 ESA Software Engineering Standards, ESA-ECSS-E-40

AD-18 Software Product Assurance, ESA-ECSS-Q-80

AD-19 Instrument Interface Document, Part B (IID-B): Planck Sorption Cooler, Document no. PL-LFI-PST-ID-002

AD-20 Planck Ground Segment Interface Requirements Document, Doc no. Planck/PSO/2002-003

1.4 Reference Documents

RD-1 Work Agreements with Internal Customers, Document no. QMS-ESOC-CTRP-PR-7430-OPS

RD-2 Document Requirements Definition for Mission Implementation Requirements Document (MIRD), Document no. QMS-ESOC-CTRP-DRD-7402-OPS

RD-3 Herschel Operations Scenario Document FIRST/FSC/DOC/0114

RD-4 Planck Operations Scenario Document Planck/PSO/2001-01

RD-5	Herschel Science Implementation Requirements Document (H-SIRD), Document no. SCI-PT-03646
RD-6	Planck Science Implementation Requirements Document (P-SIRD), Document no. SCI-PT-08584
RD-7	Deleted
RD-8	Herschel Ground Segment Design Description, Document no. Herschel /HSC/DOC/0146
RD-9	Herschel Ground Segment List of ICDs, Document no. Herschel/HSC/DOC/0150
RD-10	Herschel /Planck AIV Requirements Specification, Document no. SCI-PT-RS-07430
RD-11	Herschel Science Management Plan (SMP), Document no. ESA/SPC(97)22
RD-12	Planck Science Management Plan (SMP), Document no. ESA/SPC(97)8
RD-13	ESOC-QMS Procedure for Ground Segment Management, Doc no. QMS-ESOC-GSEG-PR-1000-OPS
RD-14	ESOC-QMS Procedure for Risk Management, QMS-ESOC-QMAN-PR-0400-OPS, Issue 1.2, January 2000.
RD-15	Orbit Data Messages, CCSDS 502.0-R-3, Red Book, Nov. 2003.
RD-16	Planck Ground Segment Design Description, Doc no. Planck/PSO/2002-002
RD-17	Planck Ground Segment List of ICDs, Document no. Planck/PSO/2004-008

1.5 Mission Objectives

The **Herschel Space Observatory** is an observatory mission. It will perform photometry and spectroscopy in the far infrared and sub-millimetre part of the spectrum, covering the 60-670 µm band. Herschel is the only space facility dedicated to this wavelength range.

The Herschel science objectives target the “cold” universe. Black-bodies with temperatures between 5 K and 50 K peak in the Herschel wavelength range, and gases with temperatures between 10 K and a few hundred K emit their brightest molecular and atomic emission lines here. The key science objectives emphasise specifically the formation of stars and galaxies, and the interrelation between the two. Example observing programmes with Herschel will include:

- Deep extra-galactic broadband photometric surveys in the 100-600 µm ‘prime’ wavelength band.
- Follow up spectroscopy of selected objects discovered in the survey.
- Detailed studies of the physics and chemistry of the interstellar medium
- Observational astrochemistry of gas and dust.
- High resolution spectroscopy of a number of comets and the atmospheres of the cool outer planets and their satellites.

Planck is a survey-type mission. Its scientific objectives are :

- To map over the whole sky (at least 95%) the temperature anisotropies of the Cosmic Microwave Background (CMB), at all angular scales larger than 10 arcminutes, and with an accuracy set by fundamental astrophysical limits (sensitivity better than $\Delta T/T \sim 2 \times 10^{-6}$).

- To map over the whole sky all major galactic and extragalactic sources of emission at the wavelengths measured by Planck (25 to 950 GHz) (galactic synchrotron, free-free and dust emission, extra-galactic compact and point sources, and S-Z effects from clusters and galaxies)
- To characterise the polarisation state of the CMB (as a goal)

1.6 Mission Overview

1.6.1 General

The Herschel Space Observatory, formerly Far Infrared and Sub-millimetre Telescope (FIRST) and the Planck Surveyor (formerly COBRAS-SAMBA) are two astronomy missions of the ESA Horizon 2000 Science Programme. Herschel was approved by the Science Programme Committee in November 1993 as the fourth Cornerstone mission. Planck was approved as the third Medium Mission by the SPC in June 1996.

Both missions carry cryogenic payloads and will be placed into similar orbits, i.e. into Lissajous type orbits around the second Lagrangian point (L2) at approximately 1.5 millions kms from the Earth. The similar orbit around L2 opened the possibility to consider a common launch with a single Ariane 5. Such solution offers significant savings due to synergy and commonality effects.

The Herschel and Planck elements of the overall mission include the flight segment, the ground segment supporting the flight operations and the associated science processing. This document specifies the requirements on the D/OPS-provided ground segment elements as well as the facilities to be provided by D/OPS in order to support both Herschel and Planck Science Ground Segments. This D/OPS provided ground segment will interface with the Science Ground Segments developed under the responsibility of SCI-SA and the PI teams.

1.6.2 Flight Segment

The flight segment consists of the two satellites, Herschel and Planck, that will be launched together. The baseline is a double launch configuration with long fairing and SYLDA 5. Satellite separation is performed by the launcher. Herschel will be released first, followed by launcher manoeuvres and SYLDA separation, and then Planck will follow. The two satellites will be separated sequentially, with a delay of a few tens of seconds.

- Herschel is separated in 3 axis mode (Z axis sun-pointing).
- Planck is separated in spinning mode (1 rpm) (spin axis anti sun-pointing)
- Separation linear velocity is 0.5 m/s between each spacecraft and the launcher.

Herschel is directly inserted into a “large” Lissajous orbit, Planck has to carry out an orbit insertion manoeuvre in order to reach its “small” Lissajous orbit.

1.6.3 Ground Segment

The Herschel Ground Segment is described in RD-3 and RD-8, the Planck Ground Segment is described in RD-4 and RD-16. The Mission Operations Centre (MOC) will be common to **both** Herschel and Planck. The location of the MOC is at ESOC in Darmstadt, Germany. In the routine phase both spacecraft will be controlled one after the other via a single X-band ground station, near New Norcia, Australia. Each spacecraft will have a daily contact period (the Daily Telecommunication Period, DTCP) of maximum 3 hours per 24-hour period (including all overheads). Other ground stations (e.g. Kourou, Villafranca) will be used during the early phases of the mission, and to provide additional coverage in case of emergency.

A dedicated Herschel Science Centre (HSC) will be set up (initially at ESTEC, then in Villafranca) by SCI-S in order to ensure overall coordination of the Herschel payload operations as well as support to the Herschel scientific community. Three Instrument Control Centres (ICC), one for each Herschel instrument, will complement the activities of the HSC. For Planck, the payload activities are coordinated through a "Planck Science Office" (PSO) located at ESTEC and set up by SCI-S. The PSO is responsible to provide the observing plan to MOC, who will implement it. Two Data Processing Centres (DPC), one for each Planck instrument, carry out instrument operations in direct interface with the MOC, and full processing of the scientific data. The ICCs and DPCs will be set up and operated by the Herschel and Planck Principal Investigators respectively.

1.6.4 Payload

Herschel has 3 scientific instruments: - HIFI, PACS and SPIRE, and Planck has two: - HFI and LFI. Their principal characteristics are given in Table 1-1. In addition, Herschel has a Visual Monitoring Camera, which will be used at the beginning of the mission, and each spacecraft has a Radiation Monitor which will be used throughout the mission.

Name	Characteristics	Principal Investigator
Heterodyne Instrument for Herschel **(HIFI)**	A heterodyne instrument which performs high to very high resolution spectroscopy in approx. 500 - 1900 GHz (160 – 600 µm) range. It is a multi-channel SIS/HEB mixer receiver with solid state local oscillators and a complement of back-end spectrometers. The SIS and HEB mixers need to be operated at a temperature of around 2 K.	**T. de Graauw** **(SRON)** **Groningen**
Herschel Photo-detector Array Camera and Spectrometer **(PACS)**	A direct detection instrument which performs imaging line spectroscopy and photometry in the 60* - 210 µm range using two bolometer arrays for photometry and two 16 x 25 stressed "bulk" Ge:Ga photo-conductor detector arrays and an image slicer in combination with a long-slit grating spectrometer. The photo-conductors need to be cooled to around 1.7 K while the bolometers have an operating temperature of 0.3 K. * Note: The PACS instrument has the facility to go down to 60 µm. However, there is no specific requirement that the Herschel system and its telescope should be compatible with this lower wavelength	**A. Poglitsch** **(MPE)** **Garching**
Herschel Spectral and Photometric Imaging Receiver	A direct detection instrument which performs imaging photometry in the 200 – 670 µm range, simultaneously covering the same field in three bands, spectroscopy in the 200 - 670 µm range, using bolometer detector arrays. The bolometers have an operating temperature of approx. 0.3 K.	**M. Griffin** **U. Cardiff** **UK**

Name	Characteristics	Principal Investigator
(SPIRE)		
Planck High Frequency Instrument **(HFI)**	An array of bolometers cooled to 0.1 K by a series of active coolers, and covering the frequency range 85 - 1000 GHz, grouped into six channels.	**J-L. Puget (IAS) Orsay**
Planck Low Frequency Instrument **(LFI)**	An array of tuned receivers based on HEMT low-noise amplifier technology operating at 20 K, and covering the frequency range 25 – 110 GHz, grouped into four channels. A 20 K cooler forms also the first stage of the HFI cooling chain.	**N. Mandolesi (TESRE-CNR) Bologna**

Table 1-1 Herschel/Planck Instruments

1.6.5 Operations

Herschel operations are described in RD-3; Planck operations are described at high level in RD-4. During the commissioning phases, part of the PV phase, and in case of contingency, the PI- teams will be required to be present at the MOC. To support them, a set of equipment provided by the PIs capable of processing and displaying the housekeeping and science data will be installed at the MOC. The equipment installed at ESOC is referred to as either the IW@MOC (Planck) or ICC@MOC (Herschel). This equipment should give the PI-teams adequate insight into the health and performance of their instruments.

Since the Herschel lifetime is limited by the cryogen boiling off, the Commissioning and Performance Validation phases will be performed during the transfer to L2 and when completed the science operations will start. In order to achieve the higher data rates and because of its larger orbit Herschel will have to re-orient the medium gain antenna to the earth. At L_2 limited scientific observations will also be conducted during the DTCP, subject to restrictions imposed by the telecommunications and other spacecraft maintenance activities.

The Planck routine phase will be conducted with the spacecraft spin axis in the anti-sun direction, with the spacecraft spinning at 1rpm. Manoeuvres will be conducted on the average every 45mins to maintain this attitude. The maximum allowed excursion from the Earth-Sun line will be such that the ground station will always be within the coverage pattern of the X-band Medium Gain Antenna (during the routine phase) such that antenna re-orientation is not required. Planck will collect data 24 hours per day, thus the observation phase is allowed to continue during the DTCP, subject to restrictions imposed by the telecommunications and other spacecraft maintenance activities. Mission planning will ensure during nominal operations that the angle between the Planck spacecraft negative spin axis (- X-axis) and the vector joining the Planck spacecraft to the centre of the Earth will remain smaller or equal to the maximum Sun/Spacecraft/Earth angle.

Both spacecraft will routinely have a DTCP of up to 3 hours. This will be used by the MOC to upload the time-tagged telecommands for the following day so that there will always be more than 24 hours of telecommands on-board. The DTCP will also be used for ranging and dumping telemetry from the on-board mass memory to the ground station. Real-time data will be transferred from the ground station to the MOC as highest priority. The data that is received from the on-board mass memory will be transferred using the available bandwidth. The capacity of the communications link between New

Norcia and ESOC will be sized to permit both Herschel and Planck data sets to be transferred in less than 24 hours i.e. before the nominal start of the next DTCP.

1.7 Global ESOC Responsibilities

The Ground Segment Manager (GSM), under the direct authority of OPS-O, is responsible for the implementation and completion of a MOC that is compliant to the H/P Project requirements (RD-13). The GSM exercises full financial, technical and programmatic control of all activities carried out by D/OPS entities, including the control over the associated industrial contracts, related to the MOC ground segment development and implementation for the Herschel/Planck mission. The GSM is assisted in his task by a Ground Segment Team (GST) whose members have assigned responsibilities for the following sub-systems and functions:

- Satellite Operations
- Simulator
- Mission Control System
- Flight Dynamics services
- Ground facilities and communications
- Ground facilities operations
- Computer infrastructure
- Integration and Test
- Mission Analysis
- Project Control
- Product Assurance

1.8 Major Programme Milestones

1.8.1 Spacecraft Milestones

Phase B Kick-Off	April 2001
System Requirements Review (SRR)	October 2001
Preliminary Design Review (PDR)	October 2002
Critical Design Review (CDR)	October 2004
Qualification Review (QR)	Beginning 2006 (TBC)
Acceptance Review (AR)	Beginning 2007 (TBC)
SVT-0	L-18 months (TBC)
SVT-1	L-12 months (Herschel), L-13 months (Planck) (TBC)
SVT-2	L-5 months (TBC)

Flight Readiness Review (FRR)	L-4 months
Launch Readiness Review (LRR)	L-1 week
LAUNCH	Aug 2007
In-orbit Commissioning Review (IOCR)	L + 3 months

1.8.2 Operations Ground Segment Milestones

Ground Segment Requirements Review (GSRQR)	June 2003
Ground Segment Design Review (GSDR)	November 2004
Ground Segment Implementation Review (GSIR)	L-1 year
Ground Segment Readiness Review (GSRR)	L-4 months
Operations Readiness Review (ORR)	L-1 month

2 FUNCTIONS AND RESPONSIBILITES

Functions and responsibilities in the various mission phases are to be found in RD-3 (Herschel) and RD-4 (Planck)

2.1 Proposal Evaluation and Assessment Studies

N/A

2.2 Design and Development

The design and development of the space segment takes place under the responsibility of the Herschel/Planck Project Team. The design and development responsibility for the ground segment is shared between D/OPS, SCI-S and the PI-teams. Overall responsibility rests with the H/P Project Manager.

2.3 Ground Segment Integration and Test

The Ground Segment Manager will prepare an overall Ground Segment System Test Plan including all elements of the Herschel and Planck Ground Segments. This will define, at a high level, the tests to be performed on each sub-system and between sub-systems. Tests will be performed with a variety of data sources, including for example, recorded data, simulated data and data from test or flight hardware.

The interfaces between the science ground segment(s) and the MOC will be tested extensively.

2.4 Validation

In order to demonstrate the compatibility between Herschel and Planck spacecraft and the corresponding ground segments a series of system validation tests will be performed with each spacecraft. They are defined as follows:

- **SVT-0**: To be carried out with the SVM only. Main objectives are to verify SVM – MOC interfaces for all Telemetry (TM) and Telecommand (TC) formats, to validate the MOC TM and TC processing systems, to validate the MOC TM and TC data bases, to characterise spacecraft behaviour, to confirm the Flight Operations Plan (FOP) data and to validate the corresponding procedures. This test is planned around L-18 months and last for a maximum of 5 days per spacecraft. The instruments are not involved in SVT-0
- **SVT-1 + EE1**: Similar to SVT-0 but with the complete satellite (SVM and PLM) including the scientific instruments. This test is planned around L-12 months for Herschel and L-13 months for Planck, lasting for a maximum duration of 15 working days per satellite (8 hour per day, 5 days per week)
- **SVT-2 + EE2**: Final verification of the integrated flight ground segment with the flight satellite interfaces and functional performances prior to launch. This test is planned for L-5 months for Herschel and L-9 months for Planck, lasting for a maximum of 10 working days per satellite.

- Listen-in tests: during specific AIV tests (e.g. TB-TV tests), ESOC will carry out on a non interference basis (without commanding of the satellite) “listen-in” tests in order to validate non command-related MOC functionality.

Prime Contractor support is required for these tests. During the SVT’s spacecraft commanding takes place via the MOC.

- *Note:*

An option is proposed to split SVT-2 into two parts one prior to shipping to Kourou and the other at the launch site.

2.5 LEOP/Critical Operations

During the LEOP, the designated Flight Operations Director (FOD) will lead the Missions Operations Team. The FOD will be responsible for all operational matters, and will conduct the operations according to the Flight Operations Plan (FOP) and associated Procedures that have been authorised by the H/P Project Manager. Deviations from the timeline or FOP must be agreed with the Project Manager or his designated representatives.

2.6 Routine and Critical Operations

The Herschel Science Centre (HSC) is responsible for taking the inputs of the scientific community for observation requests and transforming them into a coherent mission plan that obeys all of the known on-board, environmental and ground segment constraints. The Planck Science Office (PSO) carries out a similar function for Planck, though in this case takes its inputs from the Science Team, DPCs, and IOTs rather than the community. These plans are used as input for the generation of the Mission TimeLine (MTL), which is uplinked, by the Mission Operations Centre (MOC). The MOC will also respond to any unplanned situation or failure and try to recover as fast as possible.

The Ground Segment Manager will designate a Mission Operations Manager who will be responsible for the day-to-day operations of the mission.

3 ASSUMPTIONS

The following assumptions shall be made in order to generate the MIP and the corresponding Cost at Completion (CaC).

3.1 Launch Vehicle

MASS-005	Both satellites will be launched together by an Ariane 5 in its E/CA configuration.	H/P

3.2 Transfer Orbit

MASS-010	Total maximum time allocation for the transfer phase: 6 months. Expected (nominal) transfer time: 125 to 130 days. Perigee velocity and launcher dispersion correction manoeuvres planned at L + 1 and L + 2 days respectively. 2nd orbit correction (trim manoeuvre) at L + 12 days (if necessary). 3rd and 4th orbit correction manoeuvres at Tinj - 20 days and Tinj - 10 days. For Planck only: Injection onto small Lissajous orbit For Planck only: trim manoeuvre at Tinj + 2 days (if necessary). For both Herschel and Plank Commissioning and part of the Performance Verification phase will take place during the transfer. For Herchel, Science Operations (with some restrictions) will start during this phase.	H/P

3.3 Operational Orbit

MASS-015	Herschel orbit: Large Lissajous orbit around L2 (up to ca. 950 000 kms amplitude in Y direction, up to ca.400 000 kms out of ecliptic plane (Z direction). Large (above 30 deg.) Sun/Spacecraft/Earth angle. Planck orbit: Small Lissajous orbit around L2 (up to ca.400 000 kms amplitude in Y, up to ca.300 000 kms amplitude in Z). Maximum Sun/Spacecraft/Earth angle = 15 deg.	H/P

3.4 Operational Period

MASS-020	For the Herschel mission the spacecraft shall have a nominal lifetime of 3.5 years from launch till the end of the mission.	H
MASS-025	The Planck mission shall allow two full sky surveys (at least 95% of the sky) at operational orbit, which requires 15 months at L2.	P
MASS-030	Each mission shall allow up to 6 months for the transfer to L2.	H/P
MASS-032	Each mission shall allow 3 months run-down following the end of mission.	H/P

3.5 Operational Phase and Facility Utilisation

3.5.1 Pre-Launch

MASS-035	The MOC will support development activities including design reviews of flight units and systems as well as interface tests for ground systems. Close to the launch, the MOC will receive listen-in	H/P

	telemetry from the integration site and perform System Validation Tests. There is no requirement for the MOC to command either spacecraft at the launch site (but see 2.4).	

3.5.2 LEOP and Transfer Phase

MASS-040	Almost all the operations during the LEOP will be conducted in real time using only HK. The instruments will not be producing telemetry. The only active external interface will be the MOC to Software Maintenance Facility (CDMS, ACMS, STR, etc.)	H/P
MASS-045	The LEOP will be pre-planned. It will last about 2 weeks. The ESTRACK LEOP network will be used for operations in this period. The ground segment resources (in particular the ground stations) will be shared between Herschel and Planck. Continuous real time operations are therefore not possible.	H/P
MASS-050	The LEOP operations will be centred on the checkout of the spacecraft subsystems, and the navigation into the correct transfer trajectory. Telescope heating will start in this phase. The spacecraft will be transmitting only HK data at low rate, and operations will generally be conducted in RT, unless the coverage does not permit this. Data will be stored on-board, and there will be some time spent in the higher data rate modes to dump this data.	H/P
MASS-055	The LEOP can be considered to last until the first three trajectory corrections have been made, thereafter the transfer phase begins.	H/P
MASS-056	The Transfer Phase is from the end of the trajectory correction manoeuvres to injection into the final orbit at L2. Note: Commissioning and Performance Verification and the start of the Herschel routine phase are currently foreseen during the transfer phase	H/P

3.5.3 Commissioning and Performance Verification Phases

MASS-060	Commissioning includes: Complete check-out of spacecraft functions and verification of all subsystems performance. Instrument switch on and functional checkout. End of Telescope heating. For Herschel: Telescope cool-down and cryo-cover opening. Expected Herschel commissioning duration: 4 to 5 weeks For Planck: Passive cool-down to 50 K. Switch-on 20 K cooler and cool-down to 20K. Switch on 4 K cooler and cool down to 4 K. Switch on 0.1 K cooler and cool-down to 0.1 K. Expected Planck commissioning duration: 4 months (TBC).	H/P
MASS-062	Performance Verification includes: Performance verification of CDMS, ACMS and sensors calibration. Instrument performance determination and calibration Verification/optimisation of Instrument operation.	H/P

3.5.4 Nominal Mission Phase

MASS-065	The telemetry (housekeeping and science) acquired at the MOC will be archived in the Data Distribution System as files of "consolidated" data, from which it is accessible to the HSC , ICCs, DPCs and PSO.	H/P
MASS-070	The DDS is a near real-time processing system, which provides data access on a demand driven basis, i.e. the HSC/ICC/DPC /PSO are responsible for their respective data requests.	H/P

3.5.5 Post Operational Phase

MASS-080	The MOC is involved in the "Run-down" phase (a sub-phase lasting about 3 months of the complete Post-operational phase). During this phase the following activities will take place: - derivation of final spacecraft calibration accuracy data (e.g. pointing); - final spacecraft-related processing; - archiving of software and documentation; - transfer of knowledge between MOC and HSC-ICCs, and between MOC and PSO-DPCs as required; - disposal of MOC dedicated facilities;. - ICC@MOC and IW@MOC equipments returned to the PI-teams; - establishment of final Cost at Completion; - prepare a summary of all the lessons learned: "Post Mission Evaluation Report"	H/P

3.6 Satellite - General

MASS-085	The satellite will be compatible with the Herschel/Planck Operations Interface Requirements Document (AD-3), the Herschel/Planck Space to Ground Interface Control Document (AD-2) and the Herschel/Planck Packet Structure ICD (AD-4).	H/P
MASS-090	The CDMS will be compliant with the following ESA Standards: - Packet Telemetry Standard, ESA PSS-04-106 (AD-9) - Packet Telecommand Standard, ESA PSS-04-107 (AD-10) - Telemetry Channel Coding ESA PSS-04-103 (AD-6)	H/P
MASS-095	The HK data (including events, TC verification, memory dumps) and the science data will be on separate Virtual Channels (VCs). Data stored on the Solid State Mass Memory SSMM) and dumped to the ground will have a different VC.	H/P
MASS-105	The SSMM will be organised in such a way that the events and TC verification can be dumped first before the remaining HK data.	H/P
MASS-110	The dump will be prioritised on the basis of the virtual channel selection so that data of operational interest (e.g. Events, stored HK) can be dumped first.	H/P
MASS-112	Any combination of data may be downloaded during DTCP: - Live HK only - Live HK + Live Science - Live HK + SSMM dump - Live HK + Live Science + SSMM dump	H/P
MASS-115	SSMM Data storage: 2 days (with some margin) i.e. around 25 Gbits (EOL)	H/P

3.7 TT&C

MASS-120	The spacecraft telecommunication subsystem will consist of redundant X-band transponders (AD-2).	H/P
MASS-125	The uplink/downlink signals will be in the range specified in AD-2. Separate frequencies will be allocated by ESA for Herschel and Planck respectively.	H/P
MASS-130	The Low Gain Antennas (LGA's) will support an uplink high command rate of 4kbps using the 35 m station at New Norcia and a low command rate of 125 bps using the 15 m station at Kourou up to a distance of 1.8 million km from the Earth.	H/P
MASS-135	The LGA's will support the downlink of real time housekeeping data (spacecraft and payload) telemetry at a rate of 5 kbps using the 35 m station at New Norcia and 500 bps using 15 m station at Kourou up to a distance of 1.8 million km from Earth.	H/P
MASS-140	The MGA will allow for the telemetry downlink with the New Norcia 35 m station and with the 15 m station at Kourou up to a distance of 1.8 million km from the Earth during the DTCP at 15deg elevation.	H/P
MASS-145	Transponder coherent (i.e. continuous Doppler tracking) will be possible at all data rates. Ranging will only be performed in parallel with low data rate HK due to the coding scheme used at higher bit rates. Ranging will take place during a 5 min period at the beginning and another 5 min period at the end of each DTCP	H/P
MASS-150	The following data rates will be supported: - Downlink: 500 bps (low), 5 kbps (low), 150 kbps (medium), 1.5 Mbps (high) - Uplink: 125 bps (low), 4 kbps (high). High command rate possible via both LGA and MGA.	H/P
MASS-155	Probability of maximum length frame rejection in worst case conditions will be less than 10-3. Telecommands with a minimum bit transition density of 3 % will be decoded and distributed on board with a rejection rate of less than 10-3 under worst case conditions.	H/P
MASS-160	The RF-suitcase will enable the verification of all telemetry, telecommand and ranging functions and combinations thereof, as well as spectral analysis.	H/P
MASS-165	The Contractor will deliver a RF suitcase description and operation manual so that operations of the suitcase by ESOC technical personnel is possible without the need for Contractor's assistance.	H/P

3.8 On-Board Software

MASS-170	The Project will deliver, via the industrial Contractor, a Platform OBSM (On-board Software Maintenance) environment and associated documentation prior to launch. The OBSM facility will include the Software Development Environment (SDE) and a Software Validation Facility (SVF). All required SDE / SVF COTS licences will be supplied by the H/P Project	H/P
MASS-175	The OBSM facility will provide the means to generate, prepare and validate software patches or full images for uplink to the spacecraft and will be able to interface with the ESOC provided H/P Mission Control System (MCS).This interface will be defined in a dedicated OBSM facility / MCS Interface Control Document elaborated jointly between ESOC and the Contractor.	H/P
MASS-180	On-board Software (OBS) delivery from the Contractor to ESOC will cover all on board S/W (e.g. CDMS S/W, ACMS S/W, STR S/W, etc.) except instrument OBS which is PI-provided. Note: instrument software development and validation, including the generation of all software updates is the responsibility of the respective PI throughout all mission phases.	H/P
MASS-185	The OBSM facility will be available at ESOC at L-12 months. Delivery will include the necessary training and transfer of expertise to ESOC.	H/P
MASS-190	Any submission of spacecraft software updates shall be subject to a formal delivery, which includes a certification of successful validation and acceptance by the Project and a full update of the required documentation. Configuration control of the various software versions for all spacecraft on-board processors will be ensured by the MOC.	H/P
MASS-195	The Contractor will remain responsible for the OBSM task for the first year of operations. At the end of the first year the OBSM task responsibility will be transferred to ESOC.	H/P
MASS-200	Throughout the mission the Contractor will provide support to OBS anomaly investigations as required.	H/P
MASS-205	Changes affecting the functioning or the operations of the instruments will be implemented only with explicit approval of both the ESA Project Scientist and the ESOC Spacecraft Operations Manager (SOM). In addition before the implementation of software changes, any effect related to the MOC ground software will be determined and, if required, modifications will be initiated by the	H/P

	SOM.	

3.9 OBCPs

MASS-215	The Project will deliver, via the Industrial Contractor, any facilities required for the development of syntactically correct OBCPs for uplink to the spacecraft.	H/P

4 FUNCTIONAL REQUIREMENTS

4.1 Operations Centre

MFUN-005	The ground segment shall support all modes of operations -nominal and contingency- and all mission phases defined for the satellite (spacecraft and instruments).	H/P
MFUN-020	Contact with the spacecraft (Herschel and Planck) will take place nominally once per day (DTCP or daily "pass"). The ground segment design shall however allow access to either spacecraft at any time (provided ground station visibility is ensured) in case of emergency. The ground segment design shall also ensure that a "pass" can be missed without detrimental effect on spacecraft and data recovery (48- hour autonomy).	H/P

4.2 Facilities

MFUN-030	ESOC shall make available to the Herschel/Planck mission the ground facilities infrastructure required to support the mission in all its phases. This includes in principle: --The Ground Stations required for each mission phase -The operational ground communication network connecting the MOC with the ground stations in order to support telemetry acquisition, telecommanding and tracking operations as well as transmission of antenna pointing data and station monitoring and control - A Network Data Interface Unit (NDIU) -or a functionally equivalent unit (NDIU Lite)- comprising essential parts of the ground station TM and TC subsystems to support the Listen-In Tests (LIT's) and System Validation Tests (SVT's); - The Main Control Room (MCR); - The Ground Configuration Room (GCR); - The Flight Dynamics Room (FDR); - The Project Support Room (PSR); - The Herschel/Planck Control area; - The PI support area (housing ICC@MOC and IW@MOC); - The On-Board Software Maintenance (OBSM) area; - The Software Support Room; - the Simulation Room (SIR) - the network allowing data transfer between MOC and PSO and Planck DPCs - the network allowing data transfer between MOC and HSC	H/P
MFUN-035	The facilities listed above will not be used in all phases of the mission. For each mission phase the MIP shall specify which facilities will be used as well as any specific limitations/constraints attached to this usage.The MIP (or the corresponding related Applicable Documents) shall specify which features of the facilities to be used by Herschel/Planck are considered "standard" infrastructure and which features are mission-specific.	H/P
MFUN-040	The ground station network and Ground Facilities shall support the LEOP with approximately 22 hours coverage per day, the Performance Verification phase with approximately 10 hours per day, and the routine phase with 6 hours per day.	H/P
MFUN-080	In addition to the general infrastructure above, ESOC shall provide to Herschel/Planck the mission-specific elements required to complete the overall (MOC) facilities needed to support the mission in all its phases. This includes in principle: - Mission Analysis Tools (H/P) - Operations Database (H/P) - On-Board Software Support (H/P) - Performance Evaluation System (H/P) - Flight Operations Procedure Generation and Maintenance (H/P) - Mission Control System; (H/P) - Data Distribution System; (H/P) - Herschel Mission Planning/Scheduling System; (H)	H/P

	- Planck Mission Planning/Scheduling System; (P) - Herschel Flight Dynamics System; (H) - Planck Flight Dynamics System; (P) - Herschel Spacecraft Simulator; (H) - Planck Spacecraft Simulator; (P) (top level requirements relative to these systems are given in the following sections)	
MFUN-085	The MIP shall provide a description of the hardware configuration (computer facilities) required to support the systems listed here.	H/P
MFUN-090	The MIP shall provide a functional description of the corresponding software (mission software)	H/P
MFUN-095	The way in which the software is distributed between computers (e.g. real-time, off-line and simulators) shall be specified.	H/P
MFUN-100	The implementation of the mission software shall (as for all other systems) use, where appropriate, existing standard (generic) facilities and produce and/or procure only those project-specific "add-ons" required to fulfil the unique mission objectives. Note: When such generic facilities are used it is acceptable to produce only "delta-URD's" (Delta-User Requirements Documents) in order to document the specific requirements not covered by the generic system (e.g. delta-UR's for the Mission Control System requirements not covered by SCOS-2000). Similarly corresponding "delta's" for the associated lower level documents may be produced.	H/P
MFUN-105	The systems listed in MFUN-080 shall be designed in such a way that, where appropriate, maximum commonality between Herschel and Planck can be achieved. Specific solutions will only be used if justified by differences in functionality, cost and/or risk.	H/P

4.3 Mission Planning

MFUN-120	Each spacecraft shall be operated according to a programme of operations (the Mission TimeLine -MTL-) loaded by the ground during the communication period (DTCP).	H/P
MFUN-125	It shall be possible to generate a Mission Timeline covering 48 hours (or two operational days -OD's-). It shall not be necessary to re-load, during a given DTCP, the portion of the MTL (nominally one OD) which under normal circumstances is still valid and already loaded on board.	H/P
MFUN-130	The MOC shall support the MTL maintenance using the on-board editing options : There is no requirement to implement facilities to globally shift forward or backward in time sets of "commands" (spacecraft or instrument) in the MTL.	H/P
MFUN-135	The MOC shall provide to the HSC for each OD the set of observation scheduling constraints applicable to this OD (planning skeleton).	H
MFUN-140	The MOC shall accept for each OD (or set of OD's) a schedule of science observations and corresponding instrument commands from the HSC. Invalid HSC schedules shall be rejected with an indication of the error.	H
MFUN-141	The MOC shall accept requests for operations from the DPCs. MOC shall verify that the inputs from each instrument do not affect the operation of the other instrument, on the basis of procedures agreed by the GSM, the PS, and the two IOT Managers. Conflicting inputs shall be rejected and reported with an indication of the error. There is no requirement to link the DPC requests to a specific pointing.	P
MFUN-145	The MOC shall make available to the HSC the algorithms and data necessary to allow the HSC to generate a valid schedule of science observations. This includes (but is not limited to): - spacecraft predicted orbit data; - spacecraft attitude constraints; - spacecraft slew time and path prediction	H
MFUN-146	The MOC shall deliver a set of test cases and results against which the implemented software can be validated.	H
MFUN-147	The MOC shall make available to the PSO the algorithms and data necessary to allow the PSO to generate a valid schedule of science observations. This includes (but is not limited to): - spacecraft predicted orbit data; - spacecraft attitude constraints; - spacecraft slew time	P

MFUN-150	The MOC shall combine for each OD (or set of OD's) the observation schedule generated by the HSC with the associated spacecraft operations schedule, taking into account the sky visibility constraints, in order to generate a combined operations schedule. The Herschel MTL shall be derived from this overall schedule.	H
MFUN-155	The MOC shall accept from the PSO a planned pointing list as input to the planning process. Invalid inputs shall be rejected with an indication of the error.	P
MFUN-156	Deleted.	P
MFUN-160	The MOC shall combine for each OD (or set of OD's) the inputs generated by the PSO with the associated spacecraft operations schedule and instrument operations schedule (based on inputs from DPCs/IOTs), taking into account the sky visibility constraints and the DTCPs, in order to generate a combined operations schedule. The Planck MTL shall be derived from this overall schedule. The MOC shall correct the manoeuvres contained in the MTL for any systematic pointing offsets or drifts according to its latest S/C pointing model.	P
MFUN-165	The MOC shall make available to the HSC (Herschel) and to the PSO and DPCs (Planck) the Mission Timeline summary corresponding to any given operational period after successful generation of the corresponding MTL(s).	H/P
MFUN-170	The MOC shall generate in parallel to the Herschel and Planck MTL's the ground station (New Norcia) schedule corresponding to the same operational period. Note: The MOC shall determine on the basis of the previous OD's which spacecraft (Herschel or Planck) must be acquired first, and the relative duration of each DTCP. The operations must be carried out with one spacecraft, then with the other. Simultaneous acquisition is not required.	H/P
MFUN-175	The MOC shall plan (and execute) orbit correction manoeuvres as necessary, expected to be approximately once per month (orbit maintenance).	H/P
MFUN-180	The MOC shall plan (and execute) the orbit correction manoeuvres required to ensure eclipse-free operations.	H/P
MFUN-185	Planck orbit correction manoeuvres shall be performed, to the maximum extent possible, without interruption to instrument operations or the normal scanning law.	P
MFUN-190	Orbit manoeuvres shall be compliant with the defined attitude constraints.	H/P
MFUN-200	ESOC shall provide pre-launch and post-launch Mission Analysis support to the Herschel/Planck Project. Existing in-house mission analysis software shall be used where appropriate. Mission analysis shall be performed upon request. The following topics are envisaged: - launch windows calculations; - sky coverage; - ground station coverage; - orbit determination requirements; - orbit evolution and manoeuvre requirements; - eclipse profiles; - fuel budgets; - delta-V budgets; - contingency cases	H/P
MFUN-205	The time needed for satellite in-orbit maintenance operations (e.g. wheel unloading, sensor calibrations, etc.) shall be optimised (i.e. minimised) and shall take place, to the maximum extent possible, during DTCP.	H/P
MFUN-210	The MOC shall support the pointing modes defined in the System Requirements Specification (AD-1).	H
MFUN-215	The MOC shall support the pointing strategy initially as defined in the System Requirements Specification (AD-1), and finally as detailed by the PSO.	P

4.4 Satellite Health and Performance Monitoring

MFUN-220	The MOC shall provide the facilities required to ensure health and safety of the satellite (spacecraft and instruments) during the daily operations.	H/P
MFUN-225	The MOC shall maintain at all times on ground a model of the on-board status of the spacecraft for monitoring purposes.	H/P
MFUN-230	The MOC shall provide the facilities required to assess the state of the spacecraft as defined in the Satellite User Manual and check for any long-term trends that might have an impact upon the health	H/P

	or performance of the spacecraft. The evaluation system shall be able to process any HK parameter (spacecraft and/or instruments) or combination of parameters. Display and charting facilities shall be provided.	
MFUN-235	Throughout the mission ESOC shall verify RF- and TT&C compatibility between spacecraft and ground stations. This compatibility is verified prior to launch via a series of tests carried out with the Project-provided RF suitcase.	H/P
MFUN-240	In order to ensure satellite safety the MOC shall have the capability (during DTCP) to: - support the capabilities of the on-board system, as defined in the PSICD (AD-4), in real time; - exit the autonomy mode (normal operations mode) by ground command (CRP)	H/P
MFUN-245	The MOC shall provide the facilities required to support the spacecraft fault management capabilities i.e. - it shall be possible to enable, disable or reverse any On-Board autonomous function or action by ground command - it shall be possible to adjust the parameter values controlling the fault detection mechanism (e.g. confirmation time, trigger limits) by ground command - it shall be possible to modify the parameters of the Control laws and autonomous functions by ground command	H/P

4.5 Satellite Control

MFUN-250	ESOC shall ensure compatibility of the ground facilities with the ESA RF and TT&C standards (AD-6 to AD-10). Note: The H/P Project will ensure compatibility of the S/C with these standards.	H/P
MFUN-255	ESOC shall provide a Telemetry system compatible with AD-9. The TM bit stream shall be processed into separate virtual channels (VC's) allowing for extraction of the on-board data sources from the TM frames.	H/P
MFUN-260	The MOC shall be able to process all TM packets defined in AD-4 with the exception of the science data packets	H/P
MFUN-265	The TM frames shall be decoded and time stamped with UTC in order to allow a correlation of on-board clock (OBT) and UTC with an accuracy of better than 500 ms. Correlation shall be carried out on ground using the specific Time TM packets and the time stamp of frame reception at the ground station, taking into account estimated propagation delays as appropriate.	H/P
MFUN-270	ESOC shall provide a Telecommand system compatible with AD-10. The TC system shall support the execution of scheduled commands (time-tagged commands from the MTL outside the DTCP) as well as real time interaction from the MOC (during the DTCP).	H/P
MFUN-275	The MOC shall verify the correct execution of each telecommand (whether real-time or time-tagged) to the maximum extent possible via event and/or housekeeping TM.	H/P
MFUN-280	The MOC shall provide a Ranging and Tracking system compatible with AD-2 and AD-7.	H/P
MFUN-290	It shall be possible to establish and maintain two-way contact (telemetry, telecommand, and tracking data) in the X-/-X band with the spacecraft, in all attitudes, via the Low-Gain Antennae (LGA) from the New Norcia and Kourou stations. Frequency usage, data rates, modes, modulations, and formats as defined in AD-2 (SG-ICD) shall be supported	H/P
MFUN-295	The MOC shall support a mode of operations allowing: - manual commanding during the commissioning phase - a mixture of manual commanding and pre-planned operations (via the MTL) during the PV phase - pre-planned operations during the routine phase.	H/P
MFUN-300	The MOC shall fully support the satellite autonomous mode of operations (max. 3 hours ground contact every 24 hours).	H/P
MFUN-305	All operations shall be carried out according to the Herschel and Planck "Flight Operation Plan(s)" (H-FOP and P-FOP) and the corresponding "Flight Control Procedures" (H-FCP's and P-FCP's) for nominal operations and "Contingency Recovery Procedures" (H-CRP's and P-CRP's) for anomalous operations.	H/P
MFUN-310	The MOC shall ensure that no command / set of commands generated via the MTL or through manual commanding, at any time during the mission, may result in an attitude constraint or attitude restriction violation.	H/P

MFUN-315	The MOC shall be able to process ACMS sensors and actuators TM data in order to carry out attitude reconstruction as well as verification of orbit control manoeuvres on ground	H/P
MFUN-316	Deleted.	P
MFUN-320	The MOC shall be able to command every single ACMS actuator as supported by the spacecraft design.	H/P
MFUN-325	The MOC shall support all Packet Utilisation Standard (PUS) "services" defined for the Herschel/Planck mission in accordance with AD-3 and AD-4. Note: AD-3 defines the services required, AD-4, for each service, the associated "capability set" (range of functionality required within this service)	H/P
MFUN-330	The MOC shall accept from the Contractor (Prime or sub-co), install and operate the OBCP environment (system) required to develop, update and validate the spacecraft (On-board Control Procedures) OBCP's. Note: There is no requirement on the MOC to support the development or validation of instrument OBCP's other than by functional tests on the simulator (if supported).	H/P

4.6 Satellite Calibration

MFUN-340	The MOC shall maintain throughout the mission an up to date representation of the physical properties of the spacecraft, i.e.: - total mass; - mass of propellant and Helium; - position of centre of gravity in spacecraft physical coordinate frame; - principal moments of inertia (Ixx, Iyy, Izz) and principal axes of inertia.	H/P
MFUN-345	The MOC shall maintain throughout the mission an up to date representation of nominal and actual (measured) alignment data for all attitude and rate sensors based on ground as well as in-flight measurements.	H/P
MFUN-350	The MOC shall maintain throughout the mission an up to date representation of nominal and actual (measured) alignment data for all ACMS and RCS actuators based on ground as well as in-flight measurements.	H/P
MFUN-355	The MOC shall model the external forces and torques (mainly solar radiation pressure) acting on the spacecraft as function of attitude and position on the orbit.	H/P
MFUN-360	The MOC shall perform the periodic sensor/actuator calibrations required to maintain the pointing capabilities of the spacecraft within the specified value, e.g. - STR / Instrument calibration (see note); - Gyro calibration. Note: The instrument attitude reconstitution is the responsibility of the HSC and PSO.	H/P
MFUN-365	The MOC shall monitor (or estimate) the quantities of all consumables (Propellants, Coolants, etc.) and be able to predict the lifetime of each, within the limitations of the spacecraft design.	H/P

4.7 Payload Control

MFUN-375	The MOC shall carry out payload control operations as specified in requirements MFUN-295, MFUN-300 and MFUN-305. In particular: - During the non-coverage period (outside DTCP) Herschel and Planck payload control is achieved autonomously via the MTL loaded on board. - During the DTCP Herschel and Planck payload control shall be carried out according to the H-FOP and P-FOP and associated instrument procedures (H-IFCP's, H-ICRP's and P-IFCP's, P-ICRP's)	H/P
MFUN-380	The MOC shall support the "Serendipity" mode of observation for the Herschel instruments. Note: an Herschel instrument is in "serendipity" mode when it produces science TM in a uniquely defined (fixed) mode during a period of time when no observation has been requested (e.g. during slews). Only one instrument can be in serendipity mode at any given time.	H
MFUN-385	The MOC shall support the SPIRE / PACS "parallel" mode	H

	Note: SPIRE or PACS is said to be in "parallel" mode when it produces science TM in a uniquely defined (fixed) mode while the other instrument is in "prime" mode. The (reduced) bandwidth allocated to the "parallel" instrument is taken from the overall instrument allocation (i.e. no increase w.r.t. to the nominal mode of operations).	
MFUN-390	There is no requirement on the MOC to open science data packets in order to carry out payload control.	H/P

4.8 Payload Calibration

MFUN-430	The MOC shall support the Herschel and Planck satellite calibration modes (AD-1). This involves execution of multiple calibrations in order to establish the angles between stellar references and the instrument LOS	H/P
MFUN-435	The MOC shall maintain throughout the mission an up to date representation of nominal and actual (measured) alignment data for all the instruments (refer also to MFUN-360).	H/P
MFUN-440	The MOC shall be able to handle a request for pointing correction from the prime instrument ("peak up"). The correction shall only be allowed within predefined boundaries and conditions. The MOC shall: - verify that the request is legitimate (boundaries and conditions); - the correction would not lead to a violation of the attitude constraints or restrictions; - be able to update the boundaries. Note: This is relevant to real-time contact periods, for example during the commissioning and Performance Verification phases.	H

4.9 Data Provision

MFUN-455	All generated TM and TC data will be stored in the SSMM. During the DTCP the SSMM data shall be dumped at high speed to the ground station, where it shall be stored.	H/P
MFUN-460	All data that is dumped and stored at the ground station, except idle transfer frames, shall be transferred to the MOC.	H/P
MFUN-465	Upon receipt at the MOC, the science data shall be extracted and stored as raw data chronologically ordered by instrument. It shall include quality data and additional timing data in order to enable correlation of the data with respect to UTC. All other TM data (HK and event packets, TC acceptance, execution reports, event messages and anomaly reports, memory dump packets, diagnostic packets, etc.) shall also be stored as raw data.	H/P
MFUN-470	The MOC shall process all data packets with the exception of the science TM packets. In particular the MOC is not required to decompress science data. Processing shall include at least: detecting out-of-the-ordinary events, out-of-range housekeeping, and time ordering	H/P
MFUN-475	There is no requirement on the MOC to recover automatically and systematically from the SSMM data that are lost in the space-to-ground link. It shall be possible to recover data, on a case by case basis, provided that they have not been overwritten in the SSMM.	H/P
MFUN-480	The MOC shall be able to detect missing science data frames. It shall provide an indication of this occurrence to the PSO and DPC's.	P
MFUN-485	On request, the MOC shall deliver to an ICC@MOC (Herschel) or IW@MOC (Planck) its instrument TM data in near real-time (within one minute) after the packets have been received by MOC. Spacecraft ancillary data may also be required by the ICC@MOC or IW@MOC. This mechanism for monitoring TM in near-real-time will be used during the commissioning and PV phases and for instrument emergencies, but also during routine operations. Note: the MOC is not responsible for the maintenance or operation of the ICC@MOC and IW@MOC workstations. Note: The TM data also contains TC verification packets (PUS service 1), diagnostic data reporting (PUS service 3) and event reporting (PUS service 5)	H/P
MFUN-490	There is no requirements on the MOC to deliver Real Time science data (i.e. the science data collected during the DTCP) to the ICC's (Herschel) and the DPC's (Planck) during the routine phase except as part of the consolidated data.	H/P

MFUN-495	The MOC shall make available the TM data to the ICC@MOC (Herschel) or the IW@MOC (Planck) in a format from which the source TM packets generated on-board can be extracted. The data shall be delivered according to a configurable subscription list.	H/P
MFUN-500	The MOC shall deliver the "derived parameters" (also called "synthetic parameters) as well as the OOL parameters as specific packets	H/P
MFUN-505	Deleted	H/P
MFUN-510	All mission data required by the HSC, ICCs, PSO and DPC's shall be made available by the MOC on a Data Distribution System (DDS). Conversely the DDS shall be able to accept from the HSC, ICC's (TBC), PSO and DPC's the inputs (e.g. mission planning inputs, command requests) necessary for the scheduling of the instrument operations. Note: In principle, for Herschel, all required ICC inputs to the MOC shall be transferred via the HSC such that a direct connection ICC-MOC via the DDS is not foreseen.	H/P
MFUN-520	The DDS shall cover three different data types: - request for on-line data via a Web-type interface - on-line data via FTP to a specified user node - off-line full data sets on Raw Data Media (RDM), i.e. CD-ROM or DVD	H/P
MFUN-545	The MOC shall notify the HSC, PSO and the DPC's of the arrival on the DDS of the "non-regular" data. There is no requirement on the MOC to notify HSC and DPC's of the arrival of "regular" data on the DDS. Note: "non regular" data are data that are only put at non-regular intervals on the DDS, e.g. instrument memory images, S/C and instrument database updates, Solar System Objects (SSO) data base updates, instrument malfunction reports, etc. regular data are data that are deposited on the DDS at fixed, regular intervals, e.g. planning skeleton file, TC history, S/C reconstructed orbit data, attitude history data, etc.	H/P
MFUN-550	The MOC shall archive raw TM and auxiliary data throughout the mission. This Archive shall have been "consolidated" by the end of the "run-down" phase. The data and related retrieval service shall be kept available on-line up to TBD months following the end of mission.	H/P
MFUN-555	The MOC shall keep the archive off-line in a secure location for a period of 10 years after the end of the mission. A table of content of the archive shall be available in form of a catalogue. It is sufficient to store the information - retrieval tools are not required, nor data integrity checks. Storage redundancy shall be considered as a means to reduce the risk due to media damage.	H/P
MFUN-560	The MOC shall specify the DDS interfaces in Interface Documents to be agreed with the HSC, the PSO and the PIs.	H/P

4.10 Mission Operations Management

MFUN-570	The management of the mission operations shall be dictated by the need to react quickly and efficiently (during the DTCP) to failures which occurred on board during the non-visibility period. The MOC shall therefore: - collect all information available on the failure in particular assess the actions already taken autonomously on-board (FDIR) - reconfigure the spacecraft subsystems or instruments to re-establish the generation of the science data (if it had been interrupted) Note: In order to achieve this goal spacecraft and instruments must provide in the TM extensive information on the decision process followed and the actions automatically carried out in case of a failure, in particular unambiguous identification of the failure. For each foreseeable failure the corresponding CRP must exist.	H/P
MFUN-575	The MOC shall have the right to switch-off (or put in a "safe" mode) any instrument deemed to be interfering with or endangering the mission objectives.	H/P
MFUN-580	The MOC shall assume that since the Science TM packets will not be processed at the control centre any information which it needs in order to carry out nominal and contingency operations on the instruments must be included either in the instrument HK TM or in events packets.	H/P
MFUN-585	The MOC shall detect at the planning stage unsafe attitudes, which might endanger the mission or degrade scientific instrument performance (e.g. straylight). It shall be able to predict a violation, or an attitude mode, which would result in a violation of the attitude constraints or cause autonomous actions on board and veto the corresponding operations.	H/P

4.11 Additional Functional Requirements

MFUN-600	The MOC shall process and display RM and VMC packets.	H/P
MFUN-605	The MOC shall participate in the definition of the Herschel/ Planck Satellite Data Base (SDB) with the Prime Contractor see AD-3- Note: The SDB will be developed and maintained by the Prime. It will be delivered to the MOC via the H/P Project. The SDB is part of the overall EGSE and Database system, also linked to the Software Development Environment (SDE) and Software Validation Facility (SVF). The same SDB is used throughout the different phases of the AIV and flight operations. The Flight Dynamics Database is an integral part of the SDB	H/P
MFUN-610	The MOC shall accept delivery, install and maintain the SDB at ESOC. ESOC shall be responsible for the maintenance and configuration control of the SDB for the operations specific parts from the first delivery onwards (this includes therefore the instrument-specific components of the SDB's)	H/P
MFUN-615	The MOC shall accept delivery of the Herschel and Planck User's Manuals (HUM and PUM) – spacecraft and instrument parts- For each delivery the MOC shall critically review HUM and PUM and provide comments, as appropriate, to Prime or instruments (via the H/P Project)	H/P
MFUN-620	The MOC shall develop and maintain a software simulator of each satellite that can be used as a test source of realistic telemetry data and react in a realistic way to telecommands. The spacecraft simulator shall: - Model all satellite subsystems (SVM) and payload modules (HPLM and PPLM including instruments, sorption cooler, cryogenic systems), the satellite environment and the relevant parts of the ground segment - Execute in real time and realistically represent the satellite and relevant part of the ground segment behaviour as seen from the MCS - Accept all valid commands and execute those commands which would be accepted by the real spacecraft in the same mode. - Model failure cases and non-nominal modes of operations - Model the avionics processors via software modules that emulate the behaviour of the actual hardware processors. Note: this allows direct use of the actual on-board software in the Simulator, increasing realism of the model and flexibility in adapting the simulator to late changes in the spacecraft software. - Represent for both nominal and contingency situations: (i) the satellite on-board behaviour; (ii) the interaction of the satellite and its space environment	H/P
MFUN-625	The instrument simulators shall be functional models. Emulation of the instrument processors is not required.	H/P
MFUN-630	The MOC shall support on-board software management (i.e. memory load, dump, compare; configuration control of the various versions of on-board software; etc.) for spacecraft and instruments on-board software. This covers e.g. generation of the corresponding ICDs.	H/P
MFUN-635	The MOC shall provide (weekly) spacecraft orbit data messages to the JPL Horizons system in the format described in [RD-15). Note:ESA/RSSD shall arrange a contract with NASA/JPL for the operational usage of JPL's Horizons system (URL http://ssd.jpl.nasa.gov/horizons.html) for Solar System Objects (SSO) observation planning.	H/P
MFUN-640	MOC/FD shall retrieve the SSO ephemerides files for individual SSO observations from the JPL server. Note: HSC shall retrieve the ephemerides files of a predefined mission specific list of SSOs also from the JPL server.	H/P

5 PERFORMANCE AND AVAILABILITY REQUIREMENTS

5.1 Operations Centre

MPER-005	The MOC shall be dimensioned in such a way that it can support, without re-design, an extension of at least six months of in-orbit operations for Herschel and one additional full sky survey for Planck	H/P
MPER-010	The MOC shall be designed in such a way (redundancy requirement) as to avoid any outage longer than 2 hours in LEOP and 12 hours in routine operations..	H/P
MPER-015	The MOC shall be designed in such a way that at least 95% of the data produced on-board are properly received on ground, transferred to ESOC and archived.	H/P
MPER-020	The overall availability figure for the MOC operational systems shall be 95% minimum.	H/P
MPER-025	The MOC shall be designed in such a way that shall be possible to operate uplink and downlink at maximum speed.	H/P

5.2 Facilities

MPER-030	The ground segment facilities, procedures and services shall be validated and ready to support the mission at L-3 months.	H/P
MPER-035	In the event of a catastrophic failure in the ground segment (e.g. earthquake, fire) it shall be possible to re-establish essential operations within seven days (minimum duration of safe spacecraft operations supported by the survival mode - SRS MOOM-160,H/P).	H/P
MPER-040	Deleted	H/P
MPER-045	The communication network linking the various Herschel and Planck ground segment elements (MOC, HSC, ICCs, DPCs, etc.) shall be designed in such a way that with a single failure a margin of 25% throughput is guaranteed.	H/P
MPER-050	All ground stations shall be able to continue operations after a single-failure in any system apart from the antenna.	H/P

5.3 Mission Planning

MPER-060	The MOC shall uplink the Master Timeline approved by the Project Scientist one day before it is required, i.e. there will always be between 24 and 48 hours of commands stored on board.	H/P
MPER-065	On any working day, the MOC shall be able to provide mission planning inputs (e.g. for simulation/test purposes) to cover any 3 week period.	H/P
MPER-070	The MOC shall be able to generate individual daily schedules up to three weeks in advance.	H/P
MPER-075	The MOC shall be able to generate up to 8 individual daily schedules within 8 hours.	H/P
MPER-080	The MOC shall be able to produce a Master Timeline from the science inputs in less than 2 hours.	H/P
MPER-085	During the routine phase the MOC shall make available to the HSC (Herschel) the last update of a planning skeleton for a given scheduling period not later than 17 days before the uplink of the MTL derived from it. During Commissioning and PV this delay shall be reduced to TBD days.	H
MPER-086	The MOC shall make available to the PSO a long term orbit prediction for the up-coming survey based on the best knowledge of the expected performance of the orbit maintenance strategy and in the case of the first survey the expected orbit at injection to allow long term planning of the scanning strategy. The MOC shall make available every month a short term orbit file covering 2 months into the future for pointing constraint checking.	P
MPER-090	The MTL granularity shall match the spacecraft capability (one second)	H/P

5.4 Satellite Health and Performance Monitoring

MPER-100	The MOC shall initiate checks of the HK telemetry against limit values, expected statuses and status consistency within 2 seconds of the receipt of the relevant real-time housekeeping telemetry.	H/P

5.5 Satellite Control

MPER-110	The MOC shall make available to the HSC (Herschel), the DPCs and the PSO (Planck) the spacecraft reconstructed orbit data on a regular (weekly) basis.	H/P
MPER-111	The MOC shall determine the spacecraft attitude in all the pointing modes and during slews to the accuracy specified (or goal if appropriate) in the SRS.	H
MPER-115	The MOC shall make available the attitude history data for an OD not later than 8 hours after reception by the MOC of the related TM packets.	H/P
MPER-120	The MOC shall make available to the HSC (Herschel), DPCs and the PSO (Planck) the time correlation data for a given OD at the same time as the spacecraft consolidated HK TM for this period. Note: The time correlation will be used for the purpose of scientific data processing and calibration.. The time correlation data allows to unambiguously correlate S/C on-board time and UTC.	H/P
MPER-125	The MOC shall make available to the HSC (Herschel) and the PSO and/or DPCs (Planck) the TC History for a given period at the same time as the consolidated HK TM for this period.	H/P
MPER-130	Deleted in favour of MPER-140 and MPER 145.	H/P
MPER-135	For Solar System Objects (SSOs), the contribution from the MOC to the errors in the calculations shall not exceed: - 0.25 arc sec for the apparent SSO direction;	H/P
MPER-140	The MOC shall be able to predict the position and velocity (3 sigma) of the satellites to: TBDKm and 1m/s for Herschel and 500Km (TBC) and 3Km/s (TBC) for Planck.	H/P
MPER-145	The MOC shall be able to determine the position and velocity of the satellites to: TBDKm (3 sigma) and 1m/s for Herschel and 20Km(TBC) and 1Km/s for Planck (TBC)	H/P

5.6 Satellite Calibration

MPER-150	The MOC shall provide the facility to determine the remaining propellant quantities to an accuracy determined by the on-board measurement accuracy, improved by the use of 'book-keeping' techniques.	H/P
MPER-155	An attitude determination shall be completed within 5 minutes of reception of the data at the MOC.	H/P
MPER-160	The MOC shall determine the remaining Helium level to an accuracy determined by the on-board measurement accuracy.	H

5.7 Payload Control

MPER-170	The MOC shall make available to the HSC (Herschel) and PSO/DPCs the "derived" parameter data and OOL data for a given period and instrument at the same time as the instrument consolidated HK TM for this period.	H/P
MPER-175	The MOC shall make available to the HSC (Herschel) and PSO and/or DPCs (Planck) the information related to instrument mal-functions or operations problems within 1 hour of detection.	H/P
MPER-180	Telemetry routed to an ICC@MOC (Herschel) or an IW@MOC (Planck) shall arrive not later than 1 minute after the TM packets have been received at the MOC	H/P
MPER-185	The MOC to ICC@MOC interface shall support a data rate equivalent to the maximum instrument instantaneous on-board data rate (300 kbps - PACS burst mode)	H
MPER-190	The MOC to IW@MOC interface shall support a data rate equivalent to the maximum instrument instantaneous on-board data rate (130 kbps)	P

MPER-200	The MOC shall make available on the DDS the memory image of an instrument on-board processor less than 1 hour after the corresponding dump data has been received at the MOC	H/P
MPER-205	The flight dynamics analysis shall provide an a posteriori attitude determination such that a precision better than TBD arc seconds for Herschel and 0.1 arcmins (1 sigma) LOS for Planck is achieved.	H/P
MPER-210	During the commissioning and performance verification phases, a duly authorised request for an updated payload configuration shall be executed within 30 minutes of its reception, subject to the availability of ground contact with the spacecraft	H/P

5.8 Payload Calibration

MPER-220	The MOC shall monitor the status of the payload using the housekeeping telemetry in accordance with the Operations Handbook and Mission Information Base.	H/P

5.9 Data Provision

MPER-230	The acquired real-time housekeeping data shall be available in the MOC in an engineering form within 1 minute of the reception of the transfer frame by the ground station.	H/P
MPER-235	It shall be possible to make real-time housekeeping data available to the science ground segment within 5 minutes of the reception of the transfer frame by the ground station.	H/P
MPER-240	It shall be possible to make real time science data available to the science ground segment within 1 hour of its reception in the MOC.	H/P
MPER-245	The MOC shall make available to the HSC (Herschel) and to the PSO and/or DPCs (Planck) any sequence of any category of consolidated TM data from dump TM (i.e. TM dumped from the SSMM during the DTCP) not later than 10 minutes after the last "bit" of this sequence has been received by the MOC.	H/P
MPER-250	It shall be possible to recover the data stored over two days at the ground station in a single day. It is permissible to use the redundancy in the communications lines between ground station and MOC to transfer the data at high speed, but the MOC must still be able to process and distribute the data at this high rate.	H/P

5.10 Mission Operations Management

MPER-260	The MOC operations team shall be deployed and staffed in such a way that a single team of SPACONs is able to support both the Herschel and Planck mission within a single shift	H/P
MPER-265	The Mission Operations Manager or her/his deputy shall be contactable at 2 hours notice.	H/P
MPER-270	The MOC shall be able to process and successfully upload any new software within 5 working days of reception of an approved release.	H/P

6 OPERATIONAL REQUIREMENTS

6.1 Flight Operations

MOPS-005	The MOC shall manage and perform the operations of the Herschel and Planck spacecraft, and the associated ground segments, from launcher separation until mission termination.	H/P
MOPS-010	For each mission phase there shall be an operations team, which is responsible for: - planning; - scheduling of facilities; - operations and maintenance of satellite and facilities; - evaluation of operations; - evaluation of performance - reporting.	H/P
MOPS-020	Deleted in favour of MPA-150	H/P

6.1.1 Mission Planning

MOPS-050	The MOC shall plan the mission to meet all objectives for the given mission phase.	H/P
MOPS-055	The MOC shall plan the routine phase of the mission according to the requirements of the HSC and PSO.	H/P
MOPS-060	The MOC shall ensure that in the nominal case, between 20 and 51 hours of MTL are resident on-board.	H/P
MOPS-065	The Herschel mission planning cycle shall be about 3 weeks long: T-3 weeks: MOC provides planning file; T-2 weeks: MOC receives response from HSC; T-2 weeks to T-1 week: up to 3 iterations are undertaken with HSC; T-1 week: MOC releases final schedule; T-1 day: MOC uplinks schedule for T to approximately T+24 hours.	H
MOPS-070	The Planck payload will be operated according to requests from the DPC, which shall arrive at least 3 days before uplink (i.e. for execution >24 hours later).	P
MOPS-075	The MOC shall ensure that the last entry in the MTL leaves the satellite in a safe configuration if no further commands can be uplinked.	H/P
MOPS-080	The Planck mission planning will be based on the planned pointing list (PPL) produced by the PSO every 4 weeks. It will cover 4 weeks worth of pointings and will arrive at the MOC at least 3 weeks before the first pointing it contains.	P
MOPS-085	The response to a request for a modification to an existing pointing list shall be implemented within 3 days.	P
MOPS-090	Small gap recovery shall be implemented within 3 days of the detection of the gap or within 3 days of receiving a request from the PSO for small gap recovery.	P

6.1.2 Scheduling

MOPS-100	The MOC shall allocate the ground segment resources required to fulfil the mission plan taking into account the demands of other users. Unresolved conflicts shall be notified to the mission planning process for resolution through replanning.	H/P

6.1.3 Operation and Maintenance of Satellite and Facilities

MOPS-110	The MOC shall operate the satellite and ground facilities to achieve the mission plans in accordance	H/P

	with the relevant procedures.	
MOPS-115	Changes to the Operational Mission Information Base and FOP shall only be implemented after operational validation.	H/P
MOPS-120	The MOC shall maintain the spacecraft on-board software after the hand-over of responsibility (1 year after launch) until the end of mission.	H/P
MOPS-125	The MOC shall maintain configuration control of the instrument on-board software using delivered images to generate patch commands.	H/P

6.1.4 Evaluation of Operations

MOPS-130	The MOC shall measure the volume of data archived and compare it to the requirement (95% of the data, which should have been captured by the ground station).	H/P
MOPS-135	The MOC shall measure the performance and availability of the various elements of the ground systems.	H/P
MOPS-140	The MOC shall measure the performance of the space segment with respect to the specifications and expectations, in particular looking for longer term effects, which may indicate malfunction or performance degradation.	H/P

6.2 Facilities

6.2.1 Access to Operational Areas

MOPS-145	Access to all ground segment facilities shall be controlled and unauthorised access shall be prevented.	H/P

6.2.2 Support to Herschel and Planck at MOC

MOPS-150	The MOC shall provide facilities and logistical support for the HSC (Herschel) and DPC (Planck) operations staff during the Commissioning and Performance Verification phases, and other phases as necessary.	H/P
MOPS-155	The MOC shall accommodate the ICC@MOC for the entire duration of the mission.	H
MOPS-160	The MOC shall accommodate the IW@MOC for the entire duration of the mission.	P

6.3 Reporting

MOPS-165	The MOC shall report anomalous satellite behaviour within 8 hours of detection to agreed parties. Anomalies which threaten the mission shall be reported as soon as possible (goal < 30 mins) to designated persons (subject to the limitations of communications possibilities, e.g. cellular phone).	H/P
MOPS-170	The MOC shall regularly report on the mission and satellite status with a frequency dependant on the criticality of the mission operation: LEOP: daily; critical event: ad hoc; routine phase: weekly, quarterly.	H/P
MOPS-175	The routine reports shall include the status of on-board consumables.	H/P

7 PRODUCT ASSURANCE AND QUALITY ASSURANCE REQUIREMENTS

7.1 General

7.1.1 Requirements for the Quality Management System to be Implemented

MPA-005	The Ground Segment Manager shall prepare a Ground Segment Product Assurance Plan (GSPAP) covering all aspects of ESOC's ground segment contribution.	H/P
MPA-010	The Ground Segment Manager shall be responsible for ensuring the PA function of the operational ground segment, or shall designate a PA representative.	H/P
MPA-015	A Product Assurance function in accordance with the ESOC Quality Manual shall be established for all phases of the mission (i.e. the design, development, integration, test and operation of the operations ground segment.	H/P
MPA-020	All (new) ground segment software implemented for the Herschel/Planck mission shall be developed in accordance with the ECSS-E-40 and ECSS-Q-80 standards (AD-17 and AD-18)	H/P
MPA-025	The PA/QA aspects shall be addressed at each ground segment review	H/P
MPA-030	The ESOC QMS procedures for problem reporting shall apply.	H/P

7.1.2 Compliance Management

MPA-040	The PA/QA function shall be performed throughout the mission lifetime to: - ensure during each phase conformity of the outputs with the inputs from the previous phase; - ensure traceability from requirements to design for both hardware and software elements; - ensure adherence to the standards established for the mission; - ensure that all operations are carried out according to agreed procedures; - ensure that any modification to any element of the operations ground segment requested by any authorised party will be carried out in accordance to a formal Change Control (CC) procedure.	H/P
MPA-045	The PA function shall ensure requirements traceability and compliance by maintaining a compliance matrix.	H/P
MPA-050	The PA/QA function shall ensure that all elements of the operations ground segment comply with all mission requirements.	H/P
MPA-060	The PA function shall ensure that validation of the operations ground segment is sufficient to demonstrate compliance with mission requirements.	H/P

7.1.3 Non-conformance Management

It is assumed that handling of non-conformances, as well as handling of RFD’s (Request for Deviation) and RFW’s (Request for Waiver) will be covered in the GSCMP (section 7.1.4). If this is not the case the MIP shall describe how these issues will be handled for the Herschel and Planck Ground Segments

7.1.4 Configuration Management

MPA-070	The requirements for configuration and documentation control applicable in ESOC to the	H/P

	Herschel/Planck mission shall be specified in a Ground Segment Configuration Management Plan (GSCMP) to be prepared by the Ground Segment Manager.	

7.1.5 Customer Supplied Items

For the purpose of the MIRD the "customer" is the H/P Project. The Customer Supplied Items are those defined in chapter 8.5.2

MPA-075	Customer supplied items shall be received, handled, stored, controlled and used in accordance with the ESOC QMS procedures, and User's Manuals as applicable.	H/P

7.1.6 Risk Management

MPA-080	Risk Management for all activities carried out at ESOC in support of the Herschel/Planck mission shall be implemented by TOS-O in accordance to RD-14.	H/P
MPA-085	The ground segment shall provide for appropriate redundancy in its elements commensurate with the performance and availability objectives defined in chapter 5.	H/P
MPA-090	ESOC shall demonstrate that no credible Single Point Failure (SPF) in the ground segment can jeopardize the mission success. This shall be supported by the production of a Failure Mode Effects and Criticality Analysis (FMECA) covering all aspects of the ground segment and operations.	H/P
MPA-095	ESOC shall prepare a Contingency Support Activity Plan (CSAP) in order to define the planning of contingency support activities as required by the mission. Implementation into the Flight Operations Plan (FOP) and derived Contingency Recovery Procedures (CRP's) shall be addressed in the Plan.	H/P

7.2 Test Requirements

MPA-100	All operational and data processing functions of the MOC shall be tested and validated before launch	H/P
MPA-105	Subsystem, system and overall ground segment tests shall be conducted according to approved test plans and test reports shall be issued. ESOC shall define in agreement with the H/P Project the (detailed) objectives, schedule and duration of these tests. The major tests are listed in the following requirements.	H/P
MPA-110	A standard development approach shall be followed, which will require in the integration and validation phases a series of test involving all elements of the ground segment and the satellite. These tests will encompass: - the RF compatibility tests; - the System Validation Tests (SVT) involving the spacecraft linked to the Mission Control System (MCS) by a representative part of a standard ESA ground station (the Network Data Interface Unit, NDIU); - the Listen-in Tests; - the System Operation Validation Tests (SOVT) or end-to-end tests, involving all elements of the ground segment including the science ground segment; - training and simulations; - data flow tests; - mission Readiness Tests	H/P
MPA-115	Three System Validation Tests (SVT's) shall be performed with each spacecraft. The aims of the SVT's shall be: - Validation of the capability of the mission Control System (MCS) to correctly communicate with the spacecraft - Validation of the Satellite Data Base (SDB) - data base for telemetry, telecommanding and On-board software maintenance- - Validation of MCS and Flight Dynamics (FD) processes	H/P

	- Validation of spacecraft behaviour - Validation of procedures (On the real Satellite) - Validation of the MOC spacecraft simulator as a representative test tool by comparison of the behaviour with respect to the "real thing". - Collection of data sets for use in further test campaigns	
MPA-120	During specific AIV tests (e.g. TB-TV tests) ESOC shall perform, on a non-interference basis and without commanding the spacecraft a series of Listen-in tests. These tests shall be performed with the spacecraft linked to the MOC (like for the SVT's).	H/P
MPA-125	Two SOVT's (End-to-End Tests) shall be performed with each spacecraft: - EE1 (immediately following SVT1) - EE2 (immediately following SVT2) The aim of the EE tests shall be: - Validation of the overall ground and space segment behaviour and performance from end-to-end in its different operational configurations; - Validation of the mission planning process and interfaces; - Validation of the data transfer processes and access mechanisms; - Validation of OBSM interfaces for payload elements; - Validation of the HSC/DPC's capability to receive and process all the data from the MOC;	H/P
MPA-130	The MOC shall support the Overall Ground Segment Integration Tests with the HSC and DPCs	H/P
MPA-135	ESOC shall provide a Portable Satellite Simulator (PSS) in order to support pre-launch interface compatibility testing between the ground station(s) and the MOC (e.g. data flow tests, mission readiness tests, SVT's). The PSS shall be easily configurable and shall enable simulation of all telemetry formats and bit rates.	H/P
MPA-140	The adequacy of the operations procedures shall be verified by means of realistic simulators covering in principle: - execution of all nominal procedures; - execution of all foreseen contingency procedures (exceptions shall be agreed with Project).	H/P
MPA-145	ESOC shall have the overall responsibility for the definition, scheduling and conduct of the overall Herschel/Planck simulation programme.	H/P

7.3 Training Requirements

MPA-150	Adequate training shall be provided to all ESOC personnel involved in the Heschel/Planck mission (e.g. ground station staff, mission controllers, network controllers, computer operators, software maintenance, etc.)	H/P
MPA-155	Training shall take place in accordance with an approved training plan. The plan shall identify training means, duration of each training activity and number of staff involved -trainers and trainees-	H/P
MPA-160	The PA function shall ensure that the training level of all operations ground segment staff is sufficient to ensure safe and reliable mission operations.	H/P
MPA-165	Provision shall be made to train Project and Industry in the Project Support role, and in the use of the ESOC facilities.	H/P

7.4 Documentation

MPA-170	All information used for the development of the operations ground segment shall be properly documented (i.e. according to the ECSS standards used in ESOC).	H/P
MPA-175	A documentation tree shall be established to define the hierarchical relationship of all operations ground segment documents.	H/P
MPA-180	All documents shall be placed under configuration control at Issue 1	H/P

8 MANAGEMENT REQUIREMENTS

8.1 Definition of Responsibilities

MMAN-005	The H/P Project is ultimately responsible for the implementation of the Herschel Planck Mission. In this context they are responsible for the definition of the mission objectives, system requirements, spacecraft/satellite hardware and software. The H/P Project is specifically responsible for: - provision of the Satellite Database and Flight Dynamics Database; - spacecraft Telemetry provision during pre-launch Tests; - provision of access to the flight models during the SVT's; - provision of the RF-suitcase (spacecraft-ground segment compatibility tests); - spacecraft and instruments user manuals; - inputs to the Flight operations Plan (FOP); - input required to implement a software Satellite Simulator; - input required to implement the Instrument Simulators; - specialist support during all Flight operations phases; In the operational phase the remaining responsibility will be transferred to SCI/RSSD	H/P
MMAN-010	The Herschel Science Centre (HSC) responsibilities are defined in RD-5. In summary - Interface to the astronomical community - planning of the Herschel observation programme and instrument calibration; - Generation of Science inputs to the MOC mission Planning Process - production and archiving of observation data	H
MMAN-015	The Herschel ICC's responsibilities are defined in RD-5. In summary: - Analysis of instrument health and Performance - Preparation of modifications to On-Board software - Analysis of calibration data - Analysis of Science data - Delivery of software to the HSC for Science and calibration data processing - support to the MOC where specialised payload knowledge is concerned.	H
MMAN-020	The Planck Science Office(PSO) responsibilities are defined in RD-6. In summary: - Interface to the Science community - coordination and monitoring of the instrument's calibration activities - specification of the Planck data products generated by the mission - specification of the facilities required to implement the "scanning strategy" generation facility, and providing the inputs required to operate it. - resolution of anomalous operational situations involving the two instruments	P
MMAN-025	The Planck DPC's responsibilities are defined in RD-6. In summary: - Planning of instrument operations - Analysis of instrument health and Performance - Generation of the Planck mission products - archiving of the Planck data products	P
MMAN-030	The Mission Operations Department (OPS-O) at ESOC, acting on behalf of the Director of Operations (D/OPS) has overall responsibility for the design, implementation, validation and operation of the ground segment system (MOC element) and subsequent post launch operations.	H/P
MMAN-035	OPS-O responsibilities are vested in the H/P Ground Segment Manager (GSM). The GSM leads the ESOC Ground Segment Team (GST) which includes specialists from Spacecraft Operations, Data Systems, Flight Dynamics and Stations and Facilities supported at various phases of the project by participants drawn from Engineering Support.	H/P
MMAN-040	The GSM is responsible to the H/P Project Manager for the completion of a ground segment system (MOC element) corresponding to agreed project requirements (in this document and associated subordinate documents) in terms of performance, schedule and costs. A corresponding approved budget will be placed under the GSM authority from the Project Manager.	H/P
MMAN-045	Within this overall framework the GSM is responsible for;	H/P

	- defining ground segment implementation requirements based on overall mission and project requirements (in coordination with the H/P Project and the other GS implementers) ; - establishing (in coordination with the H/P Project and the other GS implementers) an overall ground segment system and operations concept and corresponding architecture of the support facilities; - managing all technical interfaces between the MOC and the other Herschel/Planck ground segment elements (i.e. HSC, ICC's and DPC's) - managing the programmatic aspects of the ground segment system (MOC element) including all costs and schedule related matters; - the implementation of the MOC; - the integration and Validation of the overall ground segment. - directing flight operations in the early mission phases;	
MMAN-050	The MOC is responsible for the following major tasks (as detailed in the previous sections) - Providing a basis for the planning process to the HSC (Herschel) and the PSO (Planck). - Planning the mission On the basis of the observation programme provided by the - HSC (Herschel) and the "scanning strategy" provided by the PSO (Planck). - Executing the observation plan (Herschel) and the "scanning strategy" (Planck). - Provision of the recovered data, pointing data and auxiliary data to the HSC (Herschel) and the DPC's (Planck). - Operation and Maintenance of the spacecraft and MOC related ground segment. - First line intervention in the event of payload anomalies according to pre-planned procedures. - Archiving the data for 10 years	H/P

8.2 Planning Requirements

MMAN-070	A Mission Implementation Plan (MIP) shall be issued by the GSM in response to the requirements specified in this document.	H/P
MMAN-075	The MIP shall be authorised by D/TOS and approved by the Herschel/Planck Project Manager on behalf of D/SCI. After approval/agreement the MIP shall serve for monitoring progress of the tasks identified therein.	H/P
MMAN-080	The MIP shall define: - the assumptions on which the implementation is based; - the operations concept; - the baseline configuration for the operations ground segment; - the preparation activities; - the operations; - the management; - the GST structure and build up; - the work breakdown structure; - the work package description. For each WP: inputs required, deliverable items, tasks specifically excluded, progress measurement points, start and completion dates; - development schedules; - cost to completion ; - the distribution of costs between Infrastructure and Project; - documentation trees; - deliverable items.	H/P

8.3 Reporting Requirements

MMAN-090	The GSM shall report to the H/P Project Manager on all operations and ground segment related technical matters, whilst being hierarchically responsible to OPS-O	H/P
MMAN-095	Quarterly Management Information Reports shall be provided. These reports should be brief and include the following information: - brief summary of the progress achieved since the previous reporting period;	H/P

	- concise description of the main problem areas, their criticality and anticipated impacts (e.g. delays in the schedule or non conformance with the requirements); - status of the technical design and operations preparation, of proposed solutions to the problem areas and of engineering, Product Assurance and testing activities; - risk status - the manpower usage showing actual versus planned and estimation at completion; - overall manpower usage chart; - update of the overall schedule with latest prediction of the completion dates of the identified milestones; - a list of relevant action items and their status.	
MMAN-100	Quarterly Financial Reports shall be provided, containing actual and expected expenditure related to Work Packages for manpower usage, facilities charges and investment.	H/P

8.4 Reviews

MMAN-120	Ground segment reviews shall be organised in conjunction with the H/P Project Team. The ground segment reviews shall be synchronised with the Herschel/Planck program reviews as defined in the Ground Segment Management Plan.	H/P
MMAN-125	The following reviews shall take place: Customer Requirements Review After release of MIRD Ground Segment Requirements Review (GSRQR) L-4 years Ground Segment Design Review (GSDR) L-3 years Ground Segment Implementation Review (GSIR) L-1 year Ground Segment Readiness Review (GSRR) L-4 months Operations Readiness Review (ORR) L-1 month Mission Commissioning Review (MCR) L+3 months.	H/P
MMAN-130	ESOC shall prepare for all the above reviews the related review procedure and associated review package. Review items corresponding to ground segment elements outside the MOC (HSC, PSO, ICC's DPC's) will be provided to ESOC via the H/P Project.	H/P
MMAN-135	ESOC shall participate in major project reviews (e.g. SRR, PDR, CDR, FAR, FRR), shall review and comment the relevant data packages, and shall be represented in the Review Board.	H/P
MMAN-140	ESOC shall provide the relevant expertise and support to ground segment and "commonality" related Working Groups (e.g. Herschel and Planck Ground Segment Advisory Groups, Herschel and Planck Ground Segment System Engineering WGs, Herschel EGSE-WG, etc.), and other reviews covering additional Ground Segment elements (e.g. "Science Ground Segment" reviews)	H/P
MMAN-145	Regular progress and coordination meetings shall be held with the Project Manager or his designated representative.	H/P

8.5 Deliverable Items

8.5.1 D/OPS Deliverables

MMAN-160	The MIP shall provide a list of "ESOC Provided Deliverable Items" covering those items to be delivered to the Project for their use or approval.	H/P
MMAN-165	ESOC shall deliver at end of mission a model of the satellite inertial properties and behaviour, to allow reconstruction and refining of its dynamics and attitude in flight history	P
MMAN-170	The MOC shall provide a SCOS OBSM environment to the PIs	H/P

8.5.2 Project Deliverables

MMAN-185	The Project shall furnish all deliverables listed in MMAN-005.	H/P
MMAN-190	The Project shall deliver a platform OBSW development environment to ESOC by L-12 months.	H/P

MMAN-195	The Project shall deliver a platform OBCP development environment by L-12 months.	H/P

APPENDIX 1: ACRONYM LIST

AD Applicable Document
ACMS Attitude Control and Measurement System
AIV Assembly Integration Verification
AMS Archive Management System
AO Announcement of Opportunity
AR Acceptance Review
APH Attitude Pointing History

CaC Cost at Completion
CC Configuration Control
CCB Configuration Control Board
CDMS Command and Data Management System
CDR Critical Design Review
CMB Cosmic Microwave Background
C/O Check-Out
Co-I Co-Investigator
Co-PI Co-Principal Investigator
COTS Computer Off The Shelve
CRP Contingency Recovery Procedure
CSAP Contingency Support Activity Plan
DDS Data Distribution System
DPC Data Processing Centre
DSRI Danish Space Research Institute
D/SCI (ESA) Director of Scientific Programmes
DTCP Daily TeleCommunication Period
D/OPS Directorate for Operations
DVD Digital Versatile Disk

ECSS European Cooperation for Space Standardisation
EE End-to-End (Test)
EGSE Electrical Ground Support Equipment
EM Engineering Model
EOL End of Life
ESA European Space Agency
ESOC European Space Operations Centre
FAR Flight Acceptance Review
FCP Flight Control Procedure
FCT Flight Control Team
FD Flight Dynamics
FDIR Failure Detection, Isolation and Recovery
FM Flight Model
FMECA Failure Mode Effects and Criticality Analysis
FOD Flight Operations Director
FOP Flight Operations Plan
FRR Flight Readiness Review
FSS Fine Sun Sensor
FTP File Transfer Protocol

GSCMP Ground Segment Configuration Management Plan
GSDR Ground Segment Design Review
GSIR Ground Segment Implementation Review
GSM (ESOC) Ground Segment Manager
GSPAP Ground Segment Product Assurance Plan
GSRQR Ground Segment Requirement Review
GSRR Ground Segment Readiness Review
GST Ground Segment Team
Gb Gigabit

HFI High Frequency Instrument
HK Housekeeping
HSC Herschel Science Centre
HUM Herschel User's Manual
H/W Hardware

ICC Instrument Control Centre
ICD Interface Control Document
ICS Instrument Command Sequence
ICWG Instrument Coordination Working Group
IFOP Instrument Flight Operations Plan
IFCP Instrument Flight Control Procedure
ICRP Instrument Contingency Recovery Procedure
IIA Instrument Implementation Agreement
IID Instrument Interface Document
IOT Instrument Operations Team
IS Instrument Station
ISO (ESA) Infrared Space Observatory
ITT Invitation to Tender
IW Instrument Workstation

KAL Keep Alive Line
kb kilobit

LAN Local Area Network
LEOP Launch & Early Orbit Phase
LGA Low Gain Antenna
LOS Loss Of Signal
LOS Line of Sight
LRR Launch Readiness Review
L2 2nd Lagrangian point of the Earth-Sun System
Mb Megabit
MCR Main Control Room
MCS Mission Control System
MGA Medium Gain Antenna
MIRD Mission Implementation Requirements Document
MIP Mission Implementation Plan
MMU Mass Memory Unit
MOC Mission Operations Centre
MTL Mission TimeLine
NDIU Network Data Interface Unit
OBCP On-Board Control Procedure
OBDH On Board Data Handling
OBSM On-Board Software Maintenance
OBSW On Board Software
OBT On-Board Time
OD Operational Day
OIRD Operations Interface Requirements Document
OOL Out of Limit
OP Observing Programme
OPS-O Directorate of Operations - Operations (Department)
ORR Operations Readiness Review

PA Product Assurance
PA/QA Product Assurance / Quality Assurance
PC Personal Computer
PDR Preliminary Design Review
P- GSAG Planck Ground Segment Advisory Group
PI Principal Investigator
PID Packet Identifier
PLM Payload Module
PM Project Manager
PR Public Relations
PRP Public Relations Plan
PROM Programmable Read Only Memory
PS Project Scientist
PS-ICD Packet Structure Interface Control Document
PSS Portable Spacecraft Simulator
PSO Planck Science Office
PST Planck Science Team
PUM Planck User's Manual
PUS Packet Utilisation Standard
PV Performance Verification
PWG Payload Working Group

QLA	Quick Look Analysis
QM	Qualification Model
QMS	Quality Management System
QR	Qualification Review
Ra	Right Ascension
RAM	Random Access Memory
RCS	Reaction Control System
RD	Reference Document
RF	Radio Frequency
RFD	Request for Deviation
RFW	Request for Waiver
RM	Radiation Monitor
ROM	Read Only Memory
RP	(Planck) Reflector Provider
RT	Real Time
RTA	Real Time Assessment
SAG	Science Advisory Group
SCI-S	Scientific Directorate-Space Science Department
SCI-SA	SCI- Astronomy Division
SCOS	SpaceCraft Operations Control System
SCP	Satellite Commissioning Phase
SDB	Satellite Data Base
SDE	Software Development Environment
SG-ICD	Space-to-Ground Interface Control Document
SIRD	Science Implementation Requirements Document
SIP	Science Implementation Plan
SPACON	Spacecraft Controller
SMP	Science Management Plan
SOVT	System Operations Validation Test
SPF	Single Point Failure
SPR	Software Problem Report
SPC	(ESA) Science Programme Committee
SRD	Software Requirements Document
SSAC	(ESA) Space Science Advisory Committee
SSD	(ESA) Space Science Department
SSMM	Solid State Mass Memory
SSO	Solar System Object
STR	Star Tracker
SVF	Software Validation Facility
SVM	Service Module
SVT	System Validation Test
S/C	Spacecraft
S/N	Signal to Noise
S/W	Software
TBC	To Be Confirmed
TBD	To Be Defined
TB-TV	Thermal Balance-Thermal Vacuum (test)
TC	Telecommand
$\mathbf{T_{inj}}$	Time of injection
TM	Telemetry
TOO	Target Of Opportunity
TP	Telescope Provider
TTC	Telemetry, Tracking & Commanding
UM	User Manual
URD	User Requirements Document
UT	Universal Time
UTC	Universal Time Coordinated
VC	Virtual Channel
VMC	Visual Monitor Camera
WP	Work Package
WWW	World Wide Web